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TRAMWAYS
THEIR CONSTRUCTION AND WORKING

HOMAS FURVES.
SSOR TO ROBERT STRUTHERS.
VALPARAISO.

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TRAMWAYS:

THEIR

CONSTRUCTION AND WORKING.

BY

J. EMERSON DOWSON,

AND

ALFRED DOWSON,

A.A.I.C.E.

LONDON:

E. & F. N. SPON, 48, CHARING CROSS.

NEW YORK:

446, BROOME STREET.

1875.

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TRAMWAYS:

THEIR CONSTRUCTION AND WORKING.

INTRODUCTION.

TRAMWAYS or street railways have now been tried so long in this country that, as far as the convenience of the travelling public is concerned, we may reasonably pronounce them a success. There is not, however, any royal road to perfection in tramways, any more than in other new inventions, the value of which must depend chiefly on the result of severe and varied *practical* tests. They have not proved faultless, but much may be learnt from the experience gained on the lines already worked; and this experience not only points out where improvements are most needed on existing lines, but will, we trust, lead to the avoidance of many errors in projecting and carrying out new lines.

To appreciate what may be learnt from this past experience, it is of course necessary to have reliable data. The subject of constructing and working tramways is, however, a comparatively new one in this country; very little has been officially recorded of what is known about English and foreign lines; and the

general information which has been published up to the present time is of the most meagre description.

We have therefore made it our study to remedy what we believe to be a want, by collecting and classifying reliable information and statistics. We have had occasion to personally visit Belgium, France, Holland, Italy, and Spain; and in India the three Presidencies, Bengal, Bombay, and Madras; and through the courtesy and kindness of many friends, we have received much useful information from other parts of the world, especially from the United States of America.

The general public being interested in the use and efficient working of tramways in this country, the subject is not narrowed to one of mere technicalities; and in now submitting to our readers the result of our inquiries and observations, we venture to hope it may be of some service, and lead to further inquiry regarding a matter which really merits consideration.

For greater simplicity and convenience we have divided the subject into the following heads:

1. *Construction and Equipment;*
2. *Working Expenses and Maintenance;*
3. *Mechanical Motive Power;*
4. *Working of Traffic, Checking Receipts, &c.;*
5. *Concluding Remarks;*

and to these we have added in an Appendix some tables of statistical returns and other particulars of tramways in America.

I. CONSTRUCTION AND EQUIPMENT.

CONSTRUCTION.

General Remarks.—In this and other countries the drivers of carts, waggons, and other vehicles, almost invariably endeavour to let them run on the tram rails, because the traction is easier for the horses; but unless the rails are several inches in width, and thus able to accommodate the varying gauges of these vehicles, the drivers cannot succeed in keeping all the wheels fairly on the rails for many yards successively. As it is, the wheels run sometimes on the rail, sometimes on the adjoining paving, and sometimes partly on both rail and paving. Moreover, when it is remembered that carts and waggons are often without springs, and heavily laden, it is easy to understand that their constant jolting on or against the rails, or along the adjoining paving, causes the permanent way to be much shaken and loosened, and worse than all, causes the paving at the sides of the rails to be worn into holes and ruts. In this way not only is the wear and tear of the tramway immensely increased, but where the paving near the rails is worn into ruts the sides of the rails are of course exposed, and offer dangerous obstructions to light vehicles. Every effort should be made in designing the permanent way of a tramway to lessen these defects, and to reduce the excessive cost of repairs.

Permanent Way.—In the United States, rails with grooves (Fig. 1) have been tried, but generally condemned. The grooves must necessarily be small, so that ordinary carriage-wheels cannot enter them, and hence they soon become clogged with dirt and stones. This necessitates the constant employment of men to clear the rails; but even then the friction is so great that it is estimated that, on an average, nearly a third more power is required to draw the cars along grooved rails than along rails without a groove, where the flanges of the wheels are free. For the same reason grooved rails add greatly to the destruction of the wheels, and are also frequently the cause of the cars "jumping" off the rails. Grooved rails also add to the difficulty of preserving the gauge, because when the grooves are not quite clear they bind the car-wheels, and the latter in their turn thrust out the rails laterally.

FIG. 1.

In many places in the United States tram rails are used with broad horizontal flanges, from 3 to 5 inches in width (see Figs. 3 and 4), so that vehicles without flanged wheels can run on them easily. Where there is a heavy cart and waggon traffic, it is more economical to make this provision in the first instance, at an increased outlay, than to adopt a system of permanent way which tempts drivers to *try* to keep on the rails, but which practically results in some of the wheels being run not on, but close to, the rails.

In Philadelphia, the city authorities require all the rails to be of a uniform section, with broad horizontal

flanges, and the gauge to be 5′ 2″, in order that vehicles of all kinds may have a smooth surface to run on, and be more easily kept on the track. By this means a more uniform direction is given to the general traffic of the streets.

A rail known as the crescent rail (Fig. 2) has been much used. It is cheap, and in outlying districts it has advantages; but there is no protection for the flanges of the car-wheels, so that they constantly ride on stones and other obstructions, and where there is much traffic this adds greatly to the wear and tear of the wheels.

FIG. 2.

Sections (Figs. 3 and 4) have been extensively used in New York, Philadelphia, New Orleans, and many of

FIG. 3.

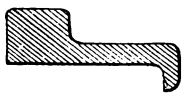
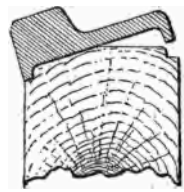


FIG. 4.

FIG. 5.



the large American cities; but these rails have a tendency to tilt, as in sketch (Fig. 5). This is chiefly owing to the unequal loading of these rails, for the car-wheels run on one side only of the rails, and the whole weight of the car is therefore brought on to that one side of the rails. This causes the timber sleepers to be more compressed and worn under the side of the rail which is most used, and it also causes an excessive strain on the fastenings of the rails.

The improved practice is not only to dispense with the lower vertical flange under the head of the rail, but to extend the base of this part of the rail, thus (Fig. 6). This rail weighs about 50 lb. per lineal yard, and is used for heavy traffic.

FIG. 6.

FIG. 7.

Where there is less traffic, the section (Fig. 7) has sometimes been used. This weighs from 28 lb. to 30 lb. per lineal yard.

In European cities, and especially in London, there are more private carriages, cabs, omnibuses, and light vehicles of various kinds, than in America. It is therefore more necessary to adopt a form of rail which offers little obstruction to the general road traffic. In the interests of the tramway proprietors, it is doubtless better not to have grooved rails; but in London and other European cities it is considered that in the interests of the public generally it is better to use them, because they do not project above the surface of the roadway or track, and therefore offer little or no obstruction to vehicles passing over in any direction.

It will thus be seen that in designing the permanent way and track of a tramway about to be laid no fixed rule can be followed; but that the engineer must carefully inform himself of the nature of the road along which it is to be laid, and above all, of the probable number and class of carts, waggons, and other

public and private vehicles likely to pass along the tramway route.

Our own opinion is that in European and other cities, where there are many public and private vehicles, grooved rails should be adopted; but the head of the rails, or that part on which the car-wheels run, should have an extra thickness of metal to allow for the great wear and tear; or, better still, these rails should be made of steel. For as the head of the rail is worn away the groove becomes shallower, the flanges of the wheels are then more worn, and very slight obstructions are sufficient to send the car off the line.

Sleepers.—When the form of rail to be used has been decided on, the next thing to consider is on what the rail shall be bedded, and how it shall be fastened. These are two very important considerations; for if the rails become loosened the gauge cannot be preserved, and the wear and tear of the cars and permanent way is seriously increased.

In the first place, it should be remembered that the permanent way of a tramway has to be considered very differently from that of an ordinary railway. In the latter, elasticity in the sleepers is an advantage, as it lessens the shock of heavy passing loads running at high speed, while at the same time these sleepers are laid in loose ballast, are well drained, easily accessible, and can at any time be packed up to their proper level. For tramways, it appears to us worse than useless to provide an elastic bed for the rails; for when the

bed of the rails is elastic, and that of the contiguous paving is inelastic, there is an unequal settlement of these two important parts. In this way the surface of the roadway becomes uneven, and ruts are formed near the rails, to the detriment of vehicles of all kinds.

It should also be borne in mind that tramways are generally laid in public roads, and are usually paved on each side of the rails, so that the whole of the sleepers and all but the surface of the rails are buried, and it is impossible to pack them up or alter their level without first removing the adjoining paving. It is therefore additionally necessary to make them of durable material, and to bed them thoroughly well in the first instance, in order to avoid the expense and general nuisance of opening up the paving.

Timber has hitherto been generally adopted for tramway sleepers, but it not only decays rapidly and requires to be often renewed, but owing to its yielding nature, and to the fact of the sleepers being frequently deflected by passing loads, the fastenings of the rails work loose, and the difficulty of securing them is much increased.

The superintendent of one of the chief tramways in New York City, a very competent authority on the subject of tramways in America, has given it as his opinion that "from long experience he is quite convinced that a perfect track for horse cars should be as *solid* as possible, and not like a steam railroad; for with the small weight of the horse car and the slow speed an elastic track sooner wears away, and gives too much

spring to the car." He considers that "a light rail carried on continuous iron sleepers will last much longer, and save much in car repairs."

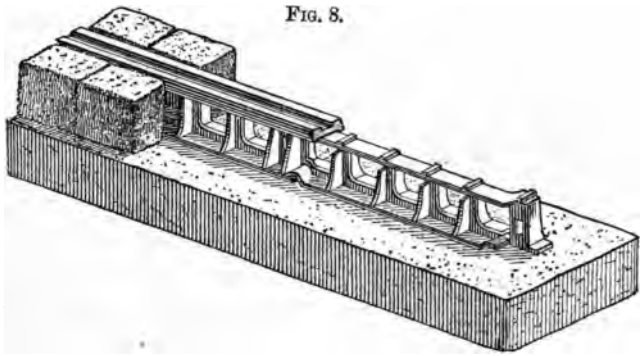
Various systems of *iron* permanent way have recently been invented, and this is doubtless a step in the right direction, although opinions differ somewhat as to the actual results achieved.

Nearly all the iron systems which have been tried consist of rails supported on iron blocks or chairs placed at intervals, the rails being specially rolled with vertical webs to prevent deflection between the supports. Hitherto the first cost of the iron systems has exceeded those in which timber sleepers are used. Among other objections, it has also been found in practice that when the rails are carried on a series of fixed points, a jolt or shock is given to the car as it rides over the supports. This is injurious to the cars, and tends to loosen the permanent way.

To meet the objections urged against the different systems hitherto tried, we have designed an iron permanent way with *continuous cast-iron* bearers for the rails, to take the place of the usual longitudinal timber sleepers. The bearers are also provided with a simple contrivance by which the rails are securely held in place. The cast-iron bearers are made in lengths of about 3 feet, and are fastened together so as to form a practically continuous longitudinal sleeper for the rails. Sufficient play is allowed in the joints to admit of the bearers being laid on the sharpest curves in use, so that no special castings are required. The rail is made

with a fillet on each side, projecting downwards: these fillets are slightly inclined inwards, and the ends of the

FIG. 8.



bearers are similarly inclined and overlap, so that a wedge can be inserted between them, and when the rail is seated on the bearers like a saddle and the wedge is tightened, not only are the bearers fastened transversely, but owing to the inclined surfaces the rail is drawn down vertically on to its permanent bed, and the whole is thus very firmly secured. The width of the bottom flange of the bearers can be made equal to that of ordinary timber sleepers, but in practice the dimensions of the castings should depend on the nature of the foundation and the traffic likely to pass over the line. There are no projections whatever beyond the sides of the rails, so that the paving can be laid in an even line, close to the rails.

This design is considerably cheaper than any with timber sleepers, and in fact we believe it is the *cheapest* of all timber or iron systems in use.

We may mention that we had occasion to design a tramway for India, where ants very soon destroy timber, and we there adopted cast-iron sleepers. Eleven miles of permanent way made entirely of iron were laid, and we are glad to be able to add that after several months' trial it has been reported on favourably.

Fastenings of Rails.—It is apparently very easy to design a secure means of fastening the rails to the sleepers; but it is really very difficult.

Where timber sleepers are used various methods have been tried; for instance, spikes or long screws driven vertically or diagonally into the timber, but they invariably work loose, and rails may be seen which are only kept in place by their own weight, and which spring and rattle when cars or other vehicles pass over them.

Sometimes rails with vertical webs at the sides are used, and "dogs" or staples are driven horizontally through these webs into the sleepers. These staples are much better than spikes or screws, but they are not entirely satisfactory. Another plan is to pass bolts through the rails and sleepers, with nuts on the under side of the sleepers. This is, of course, a bad arrangement, for the bolts can never be tightened or adjusted without removing a long length of rail, sleeper, and paving.

A further objection to all these fastenings is that they admit water into the heart of the timber; they rust, and from constant vibration make excessively large holes, so that on the whole it may be safely

asserted that no really satisfactory fastening can be made when timber sleepers are used.

It is more easy to design a secure fastening for *iron* sleepers and rails, and, as we have already mentioned, we have been able to provide a very simple and efficient one.

Transverse Ties.—The continued trampling of horses between the rails tends to spread the track, and to force the rails out of gauge. To some extent this may be prevented by having the paving outside the rails well laid and rammed; but it is also desirable to connect the opposite sleepers by transverse ties. The ties should, however, be kept well below the paving, to prevent their being affected by any sinking of the stones.

Paving.—The next important consideration is as to the cheapest and most suitable material for the horse track. This should, to a certain extent, be regulated by the amount and nature of the traffic likely to pass over the tramway, for what may be requisite in a busy thoroughfare, cannot be equally necessary in an outlying district. In England, it is customary to use paving of granite or asphalt between the rails, and 18 inches outside of them. The cost of such paving is generally not less than half the total cost of the tramway. In America, the horse track is formed of macadam, wooden-block paving, stone setts, or cobble stones.

Asphalt gives a bad foothold for the horses: it soon wears away near the rails, and is difficult to repair in wet weather, so that it is not considered a good paving for tramways. Granite is very durable, and if carefully laid and attended to, its surface can be kept

fairly even; but it is certainly difficult to keep the edge exactly on a level with the rail. The stones should be nearly of the same size, to prevent unequal settlement; for if stones of large and small area are mixed, the smaller ones will sink sooner than the others, as their bearing surfaces are less.

In England, several tramways have been laid on roads which had previously been macadamized over their whole width; but as the tramway horses must always run to and fro in the same line, and as so many other vehicles are also driven along the tramway track, it has been found necessary to substitute a more lasting material than macadam for the horse track. In many places this has, however, led to a serious inconvenience to the public. The owners of the macadamized roads in several instances declined to incur the expense of paving the roadway on each side of the tramway, and the natural consequence is that, owing to the macadam being less durable than the stone paving, ruts are worn in the former where it adjoins the tramway paving, so that the surface of the latter is higher than the macadam next to it, and the edge of the paving is often a serious obstruction to passing vehicles. More complaints have been made against tramways on this account than on any other, and until the road authorities adopt a more reasonable and less short-sighted policy, we fear the nuisance will not be abated. This backwardness on their part is the more inexcusable, because they are relieved by the tramway companies of the up-keep of the whole width of roadway occupied by the

tramways, which represents an annual saving in many instances of several hundred pounds per mile.

An improved method of wooden-block paving laid on horizontal boards, and grouted with a mixture of pitch, gravel, &c., has been recently tried for short lengths on two or three English lines, and we think it promises to answer well.

The greatest difficulty in paving (of whatever material) is to keep the surface of the rails and of the adjoining paving on a uniform level. Unless this is effectually done ruts are sure to be formed, as already described. Moreover, tramways are often laid, and are, generally speaking, of most use to the public in streets where there is the greatest traffic, and where, consequently, there is immense wear and tear, and where ruts are most quickly formed. Every attention should therefore be given to this very important subject.

In our opinion, the best plan, in London and other European cities, where there is a very large number of public and private vehicles, will be to use a grooved rail, not exceeding about three inches in width, and to have wooden-block paving uniformly laid on horizontal boards, as above described, over the whole of the roadway, from kerb to kerb, the sleepers to be of iron, and to be placed on the same horizontal boards as the paving-blocks, so that there can be no unequal settlement of the rails and paving. To preserve the wood and to prevent its absorbing moisture and impurities, it should be "Burnetized," a well-known process of impregnating wood with a metallic solution.

With such an arrangement it will be more easy to have the repairs of the whole width of roadway, between kerb and kerb, effected by one responsible body. The tramway company should be made to execute all the repairs, to the satisfaction of the road authorities, and the latter should pay them a fair proportion of the cost of repairs. No disputes could then arise as to who should be answerable in the case of accidents, and a source of great public inconvenience and even of danger would be removed.

The question as to how the roads on which tramways are laid can be best kept in repair was specially brought before the Select Committee of both Houses of Parliament appointed in 1872, and they reported:

"That public interests require that the road should be kept in perfect repair and under one management, which can be best secured by the tramway company being obliged to repair the whole road in such manner as the road authorities may direct, receiving from them an annual sum, to be settled by contract, sufficient to keep in repair that portion of the road for which they are responsible."

Foundations.—Having ascertained the probable nature of the traffic of all kinds likely to pass over the tramway, and having determined the class of permanent way to be used and the bearing surface to be given to the sleepers, great care should be taken to provide a sound and lasting foundation, not only for the sleepers, but for the adjoining paving, so that both may be kept up to a uniform level.

In England, the use of lime or cement concrete has almost invariably been adopted; but it is doubtful if in all cases this is either necessary or desirable. In this country it generally happens that tramways are laid on roads which have been in use for many years, the metalling of which is many inches thick and very hard. In such cases it is better to remove only so much of the existing road material as will admit of the permanent way and paving being laid, after the bed has been well rammed and brought to an even surface.

Where it is necessary to provide new foundations we are inclined to rely on the use of clean gravel or other suitable material, mixed with boiled tar to render it impervious to water, provided it is *thoroughly well rammed.* In our opinion, almost as much depends on ramming the foundation as on the material used.

General Principles of Construction.—From the foregoing remarks it will be seen that varied experience shows that the following principles should be adhered to in designing tramways, viz.:

1. The rails should be laid *dead*, on a bed as unyielding as that on which the paving on each side is laid.
2. The sleepers should be of durable material, laid on a solid and lasting bed, to avoid the necessity of disturbing the roadway for repairs.
3. The fastenings of all kinds should be few and simple.
4. The track should be well drained, to prevent the accumulation of water.

5. The use of timber sleepers should be avoided, because they soon perish, because they are elastic, and because fastenings attached to them soon work loose. Besides this, in tropical climates timber is rapidly destroyed by ants and other insects.
6. The permanent way should be designed not only to meet the wear and tear of public vehicles, heavy waggons, &c., passing over it, but to resist the great transverse strains caused by these vehicles when driven against the rails.

The English Tramways Act provides:

"That tramway companies shall repair, with such materials and in such manner as the road authority shall direct, and to their satisfaction, so much of the road whereon any tramway belonging to them is laid as lies between the rails of the tramway, and (where two tramways are laid by the same company in any road at a distance of not more than 4 feet from each other) the portion of the road between the tramways, and in every case so much of the road as extends 18 inches beyond the rails on each side of such tramway."

But by a curious oversight no provision is made for the maintenance of the rails and sleepers, and the foundation on which they are placed.

It is true that all tramways in this country, before being opened for public traffic, must be officially inspected by a Government inspector and "certified to be fit for such traffic"; but as this inspection is not held until after the lines are finished, when all but the upper surface of the rails and paving is out of sight, it practically means that the inspector can do little more

than see that the clauses of the Act of Parliament have been complied with, and that the lines have been laid in the positions shown on the deposited plans.

Now, seeing that tramways are laid in public streets, and that so much depends on the design of the permanent way, on the class of paving to be adopted, on the mode of preparing the foundation, and on the facility of keeping the whole tramway in such a state of efficiency that the public will not be inconvenienced, it is most essential that the preparation of the working drawings and specifications should be entrusted to engineers experienced in tramway work. The ratepayers, through the road authorities, should also make it very clearly understood that they will in all cases stringently enforce the powers reserved for them in the Act, and will *compel* the tramway company to keep in thorough repair not only the paving between the rails and immediately on the outside of them, but the rails and sleepers also. Directors would then more often realize the importance of the best attention being given to the design of the permanent way and the mode of constructing the tramway, and the public would not infrequently be spared much avoidable inconvenience.

EQUIPMENT.

Cars.—It is evident that the carriages on a tramway are subject to much less severe treatment than those on an ordinary railway, where the rate of speed is very great, and where a number of carriages are fastened

together, and often knocked violently one against another. On the other hand, the motive power used on a tramway is much less than on a railway; and the weight of a tramway car must be so regulated that when loaded with passengers it will not be too heavy for a pair of horses. Only experienced makers can be trusted to build a car sufficiently strong and at the same time sufficiently light.

In Europe, cars drawn by two or more horses have almost invariably been adopted, but in the United States there are many tramways on which one-horse cars are used. The average weight of two one-horse cars is greater than that of one two-horse car, and so with the former each horse has more dead weight to draw than with the latter. But where the traffic is not very great, or where cars must be run at short intervals of time, whilst the number of passengers likely to ride in any one car does not exceed twelve or fourteen, it will be generally found best to use one-horse cars. The latter have also the advantage of not always requiring conductors, for the driver can attend to the few passengers; and in the United States such cars are usually fitted with a glass fare-box, in which each passenger deposits the exact amount of his fare, so that it can be seen by all his fellow passengers, who can at once detect any error. The box is not under the control of the driver, and he merely has to see that each passenger deposits his fare correctly before leaving the car. The driver is furnished with a bag of small change, in case any passenger really requires it.

It is especially necessary to have light cars where the gradients are steep, and in hot climates where horses are easily distressed; and in designing a tramway car, care should be taken to avoid an excessive overhang at the ends, especially when the usual kind of brake is applied from that part of the car, for then the strains from the brake and load pull down the ends, and cause the car to be "hog-backed."

Great difficulty is experienced in getting suitable wheels for tramway cars, for either they are clumsy and heavy, or they are liable to be easily worn or broken. At present tramway wheels are generally obtained from the United States, owing to the toughness of the American chilled castings; but the Hadfield Steel Foundry Company, of Sheffield, have recently succeeded in producing some cast-steel wheels of good design, which are light, and represented to be strong and durable.

A new method of stopping and starting cars has been recently invented by Messrs. Betteley and Davison, which, if successful, will doubtless effect a saving in the cost of working. The car is stopped by means of an endless chain geared on to small drums and wheels attached to the axles. With this mechanical arrangement the ends of the car will not be pulled down, as with the ordinary brake, and fewer brake-blocks will be needed. Another feature of this invention is that when the brake is applied to stop the car, the revolutions of the axle are to cause the chain to wind round a drum, and in doing so to pull against a strong fixed spring.

This spring, when released, is intended to start the car without aid from the horses being necessary. Trials are, we believe, about to be made with a car fitted with these appliances, and it will then be known how far they may be considered practically successful.

Horsing of Cars.—The number of horses required per day to work a car depends on its weight; on the gradients; and last, but not least, on the frequency of the stoppages. In a good climate, a well-conditioned horse suited for this kind of work should be able to draw its load from 15 to 18 miles per day. But on busy routes there are so many stoppages, and the horses are called on to make such great and frequent exertions to start the heavy dead weight behind them, that they cannot usually draw a tramway car more than from 13 to 16 miles per day. It is also necessary to provide extra horses to take the place of sick or injured ones, and in practice the usual allowance in this country is about eleven horses per car per day, the car usually travelling from 60 to 70 miles each day.

Cost of Construction and Equipment.—We have not here attempted to give an estimate of the cost of constructing and equipping a tramway; for not only is the cost of materials, horses, horse-keep, and labour different in every country, but that of iron, which is so considerable an item in the construction, fluctuates so much in every country that an estimate given now might be very misleading in a few months' time.

II. WORKING EXPENSES AND MAINTENANCE.

WORKING EXPENSES.

We have detailed statistics of a large number of tramways established in various parts of the world: they are, however, chiefly those of lines in the United States, because there are so many more in that country than elsewhere, and because it is more easy to obtain reliable information there on the subject. In the State of New York and other leading States, every tramway company is, by law, obliged to file, in a prescribed form, in the office of the State Engineer, an annual report of the operations of each year, such report being verified by the oaths of the treasurer or president, and acting superintendent of the line.* These reports are classified, and embodied in the annual official Report on Railroads of the State Engineer and Surveyor. His report is printed and circulated among the senators and others interested in the subject, and the "whole expense thereof is refunded to the Treasury of the State by an equitable assessment, by the comptroller, on the several railroad companies of the State." The expense to each individual company is small, and in the interests of the public it is very useful to have such authentic returns published. In England the railway companies are required to send

* See Appendix (B).

annual returns to the Board of Trade, but, as yet, tramway companies are not required to do so. We, however, trust they will soon be obliged to file authenticated accounts, so that the public may be better able to test and profit by the experience gained by each company.

In the Tables in Appendix (A) we have given the returns of fourteen horse-lines in the State of New York, the returns being taken from the State Engineer's reports for the years referred to. On reference to these Tables, our readers will not fail to notice what a very large percentage of the gross receipts is usually absorbed by the expenditure—from about 70 to 80 per cent., and sometimes even more; and this result is the more striking when it is remembered that the total expenses of ordinary steam railways do not usually exceed from 45 to 50 per cent. of the gross receipts. The fourteen lines above referred to are, however, no exception to the general rule. We have worked out the official returns, for the last five years, of forty-two American lines, and we find that the percentage of the total expenses on the receipts varies from about 65 to even 95 per cent., and gives an average of a little over 80 per cent.; and a very similar result attends the working of tramways in Europe. This heavy expenditure is chiefly owing to the great cost of horse renewals and horse-keep.

Cost of Working.—The cost of wages, horses, and horse-keep varies in nearly every country, and in different localities in the same country, and we have

already seen * that the number of horses required per car per day depends on its weight, the steepness and number of the gradients, and on the frequency of the stoppages. All these circumstances must be taken into account in estimating the probable cost of working a tramway, and it would be useless to give details here for any particular country or locality. We may, however, mention that the average working expenses per two-horse car in the United States, exclusive of the cost of administration, vary from about 2*l.* 5*s.* to 3*l.* a day; and per one-horse car (generally without a conductor) from 1*l.* to 1*l.* 10*s.* a day. The president of the Seventeenth and Nineteenth Streets Railway Company, Philadelphia (Mr. Joseph E. Gillingham), who has had a large experience in tramways, and who has kindly furnished us with much useful information, states that these expenses, on a line six miles long, in that city, are estimated at about 2*l.* 12*s.* per day. In Belgium, Italy, and Spain, the working expenses, exclusive of the cost of administration, vary from about 1*l.* 10*s.* to 2*l.* per car per day. In England these expenses vary from about 2*l.* to 2*l.* 10*s.* per car per day.

The London General Omnibus Company run their omnibuses about 60 miles a day, and the present cost of horses and wages for each omnibus, per day, is about 2*l.* 2*s.* This company's management of horses is more economical and generally superior to that of any London tramway company; but it is also a fact that tramway horses have harder work to do than omnibus horses.

* Page 23.

Horses are costly to buy and to keep: they soon depreciate in value, and everyone who has kept only two or three probably knows, from painful experience, how soon they may be injured or unfitted for regular work, and how difficult it is to prevent stable servants from being wasteful, dishonest, and inattentive. Tramway companies have often to keep up several hundred horses in good going condition, and it may be readily imagined that the task is almost Herculean. Practical knowledge and careful supervision can alone ensure economical management, and every care should be taken by a tramway company to secure the services of a thoroughly good and trustworthy stable manager.

The North Metropolitan Tramway Company, who have about 29 miles of double line open, contract with the London General Omnibus Company for the horsing of the tramway cars. The latter company adopt the plan of training young horses in their omnibuses, and of then drafting them off for use on the tramway, so as to avoid the risk of raw or jibbing horses stopping a car and blocking the line; but although only tried horses have thus been used on this tramway, the Omnibus Company have found, after more than a year's experience, that the tramway cars tell more severely on them than the ordinary omnibus.

MAINTENANCE.

Repairs of Tramway.—The cost of keeping in repair the permanent way and track of a tramway depends on

the amount of traffic of all kinds passing over the line, and on the excellence of the design and construction of the tramway. When paving is used instead of macadam there is a great saving in the cost of up-keep, and, beyond having occasionally to renew some of the materials, nearly all that should then be required is to keep the paving in good order, and to draw in and straighten the permanent way. Constant attention is, however, necessary, and on the principle of "a stitch in time," repairs should not be neglected, not only from an economical point of view, but to prevent the public from being inconvenienced by defects in the road.

We have already pointed out how necessary it is for the road authorities to adopt very stringent measures to ensure the permanent way and paving being kept in thorough repair by the tramway company. There are instances where, from disagreement with the local authorities, the tramway company have failed to keep their track in good order; but as the chief sufferers are the public, no mere dispute with the local authorities should be taken as an excuse for such neglect, and it should on no account be allowed. The tramway company should be *compelled* to keep the permanent way and paving in good condition, and unless they do so efficiently, the road authorities should enforce the powers specially provided for them in the Tramways Act, "and do the works necessary for the repair and maintenance or restoration of the road," and make the tramway company repay whatever expense they may thus incur.

Repairs of Cars.—We have already referred to the necessity of reducing as much as possible the dead weight of the cars. To effect this, and at the same time to make the cars stiff and strong, is no doubt very difficult; but it is possible; and every care should be taken to see that it is done. Even the best made cars suffer much from the constant jolting and straining they are necessarily subjected to. They should be frequently examined, and all necessary repairs executed promptly.

III. MECHANICAL MOTIVE POWER.

Tramways in nearly all parts of the world are at present worked by animal power, and the great cost and risk of keeping a large number of horses have already been referred to. On a few foreign lines steam power has been partially tried, but on so limited a scale that the practical results hitherto produced have not been sufficient to obtain a satisfactory decision on the subject. The opinion is, however, gaining ground that steam power can with safety and advantage be used instead of animal power in several places, and many think that it can be made to effect an important saving in the cost of working.

Captain Tyler, R.E., one of H.M. Government Inspectors, has called attention to the probability of such a change in the motive power being adopted, and in a report to the Board of Trade he says:

"It seems probable that the introduction and extension of the rail system will lead, sooner or later, to the employment of other than horse power for the movement of vehicles, if not through the streets, at least along the roads of the districts surrounding the Metropolis; and it is undeniable that such a step in advance would have, at all events, one good effect, in avoiding the wear and tear to the road surfaces occasioned by horses' feet, and in thus doing away with that which is, after all, most destructive to the road surfaces."

We have already mentioned that the success of a

tramway depends very much on good management and careful supervision; but even assuming that there is perfect management, and that horse food is advantageously bought at cost prices, it will be well to bear in mind that in all probability the cost of horses and horse-keep, wages, and general expenses will increase rather than decrease. At all events, such seems to be the tendency of the present day, and so it becomes additionally important to consider any practical suggestions for reducing the present excessive cost of working expenses.

Steam, electricity, hot and compressed air, and various kinds of gas, have all been suggested as motors for tramway cars, but, so far as we are aware, the only engines capable of bearing the severe test of actual use are those worked by steam power: and even among the latter there are very few likely to prove suitable and safe. The puffing noise and the escape of steam, the glare from the fire, all contribute to frighten horses, especially at night, and if permitted in the public streets would, without doubt, cause many accidents.

To meet these difficulties many expedients have been tried, and among them that of Dr. Lamme, of New Orleans, who invented a small locomotive with a boiler containing about 60 cubic feet of water, but to which no fire or heating apparatus was attached. The process is thus described:

"When it is required to start the car, the boiler is nearly filled with cold water, and the locomotive is run alongside of a large stationary boiler, working at a pressure of 200 lb.

The steam pipe of the stationary boiler is connected with the locomotive boiler, steam then rushes into the latter, and in a few minutes it raises in the cold fireless boiler a pressure of 180 lb. The connection with the stationary boiler is then uncoupled, and the fireless locomotive is ready for work."

General Beauregard and others took much interest in the invention, and experiments were made in New Orleans and elsewhere which were tolerably satisfactory, provided the road was level and there were very few stoppages; but gradients and frequent stoppages tell heavily against the limited power of the "fireless" engine, for every minute adds to the loss of heat by radiation, &c. Tramways are seldom, if ever, without inclines, and the cars must be frequently stopped for passengers to get in and out, and for these and other reasons this invention is not considered a practical solution of the difficulty.

Mr. L. J. Todd has for some time been conducting experiments in this country on various kinds of engines designed for tramways, and as he has much practical knowledge of the subject, we think it well to give the following extracts from a report he has kindly furnished us with. He says:

"For most street railways it will, for many reasons, be preferable to use the ever constant and ample power of an accumulator furnace boiler, as then the car will be more independent and better able to meet the strain of temporarily increased traffic during certain hours of the day and certain days of the week. And in running a great number of rapidly succeeding cars, if one becomes disabled, the succeeding car

of an accumulator can easily drive this before it, and thus clear the line; while, with the weak powered fireless engines, the lines would probably be blocked, and the longer the cars waited the less would their propelling power become. It is also possible, and very probable, that the great crowds on public holidays would quite disorganize a traffic carried on by fireless engines, if their power cannot be in any way increased against emergencies; whereas the accumulator, by running its fan harder or slightly lessening its speed, can vastly increase the total power given out during a run. The accumulator car can also run an entire day without coming into the shop, whereas the fireless engine must, at every journey, be run into the shed for that supply of driving heat which the accumulator boiler is, while at work, constantly receiving from the fuel in its small furnace, and storing for use when required, in precisely the same medium as used in the fireless engine, viz. a great mass of water."

"From the point of requiring the least attention while working, the 'fireless' boiler is of course decidedly pre-eminent, but from the very nature of it, its power must ever be of the most limited and irregular description; in fact, the action of such a boiler is precisely similar to that of a large spring, which although at first powerful is yet ever decreasing in pressure as it uncoils."

"In an 'accumulator' boiler the water capacity is so large in proportion to the grate, that the pressure cannot possibly rise dangerously while the engine is running, nor even rise at all except very slowly; and again, the water capacity *above* the low-water level is equal to the entire evaporation of half an hour, or even an hour's full work. The fire also does not require attention while running, as the deep narrow furnace is merely filled with coke at starting, and is then left, like a small cupola, to sink down during the half-hour's

run. And so, provided the driver merely fills his boiler with water and his furnace with coke before starting, he may then with perfect confidence leave it to itself during the run, as the factor of safety is abundantly great.

"For the production merely of a small power, and where only intermittent attention can be given, this accumulator is essentially and truly a 'safety' boiler; indeed, it is the only furnace boiler yet designed which can safely be put into a steam car, or street locomotive, which has *only one attendant.* The 'accumulator' principle is obviously, of course, inapplicable to large boilers, or to the production of great powers, but for the very limited power required for a street car all its parts can readily be kept within ordinary and safe dimensions and thicknesses of plates."

"In carefully considering the various requirements of actually working a street railway by steam power, it seems far preferable, whenever possible, to use detached engines to pull ordinary cars, rather than to attempt the combination of engine, boiler, and passenger carriage into one machine. Where, say, fifty or sixty cars have to be under steam and on the street daily, it will at once be seen how much easier it will be to repair, clean, and keep in order their boiler and engine motions when these are separate, as the locomotives can then be run into a separate repairing shop, so that the fittings, trimmings, and painting of the passenger carriage are kept clear from the smoke and dirt of the repair shop, and also from the lighting up and running shed.

"With a detached engine the passenger car is also kept perfectly clear from any smell of hot oil or tremor of machinery: and, again, if any slight escape of steam takes place or accident occurs to the engine, the passengers are not needlessly alarmed, as practice has already proved them to be with a self-contained machine. And, again, there is a strong feeling on this point on the part of the general public,

as ninety-nine out of every hundred travellers would prefer to travel in a separate passenger carriage rather than to enter one where part of them would actually sit on top of, and others lean their backs against the boiler. And however successful self-contained steam cars may be from a mechanical point of view, it is doubtful whether such machines will ever become popular favourites.

"In reference to this, some have remarked that as passengers are not at all afraid to go on board a steamer, which has a boiler below the deck, therefore they will not object to the steam cars; but it must be remembered that in the steamer there are a number of skilled men to constantly attend to the boiler and gear; while the leading idea among the present designers of steam cars seems to be simply to stow away one or more boilers out of sight within the car, and then leave them and the passengers to take care of themselves."

Referring to a means Mr. Todd has invented of working a steam engine in silence, while at all times he is able to regulate the pressure as in a locomotive with the ordinary blast-pipe, he says:

"The ordinary blast in the funnel has one great practical advantage and convenience, in that it at all times perfectly regulates the intensity of the draught to the ever varying amount of power that a locomotive gives out. If the engine be going up an incline, the blast becomes very strong, and there is plenty of steam. Again, when descending, the blast is soft, and raises no excess of pressure; so that either in running heavily up or lightly down a gradient, the pressure-gauge hardly varies. This one advantage is of such great convenience and utility, that engineers do not like to part with it; they therefore universally adhere to the contracted exhaust in the funnel, and, in special cases, merely try to

lessen the noise by making the steam issue through a number of small holes instead of one large one, or through a narrow annular opening; or they use an adjustable nozzle, or some other device. But with all these schemes, one main fact must not be lost sight of, viz. that the gases *must* issue from the funnel at a certain velocity, or the boiler will not keep steam; and that to maintain this velocity the exhaust *must* be projected into the funnel at a certain great speed. Now, the noise that the exhaust makes depends wholly and entirely upon the speed with which it issues from the blast nozzle. It is extremely easy to avoid noise, either by making the blast opening sufficiently large, or by making the rate of exit sufficiently slow; but then, of course, the velocity of the draught is not maintained, and there is in a locomotive literally no choice between the two evils: either the exhaust must issue, through whatever kind of opening, at a certain great speed, thereby making noise but keeping steam; or if the noise is reduced, which means that the exhaust has a large opening, then the boiler is spoilt for making steam."

"Others have entertained the idea that if the exhaust could be made to issue in a constant stream, instead of separate blasts, it would then frighten horses less. But this hope has not been realized in practice; and even were it possible to attain this constant stream, yet still the other objections to a funnel exhaust-blast for a street locomotive remain unremoved. And to show of what small avail this constant stream is in lessening the alarm of horses, it need only be mentioned that an ordinary small jet cock in the funnel frightens horses so much, that it must always be shut off when they are passing, even although the locomotive be standing. The plan has also been tried of fitting road locomotives (having an ordinary proportion of boiler) with an air or other condenser, into which the exhaust can be

turned for a short time while passing horses; but what is wanted in a street is constant, and not intermittent silence. Further, an engine fitted with such a condenser has to depend entirely upon the ordinary blast-pipe for its power of making steam; and as the exhaust is not constantly in the funnel, it follows that when at work the blast-pipe must do, during a certain time, work that should have been spread over a longer period. To enable it to do this, the nozzle must be more contracted than usual; and so, for the advantage of being silent at certain short times, such an engine pays the penalty of making more noise than usual on other longer occasions—a result most out of place in a street. A moment's reflection will also show that a similar and better result than this can be readily attained by merely using an adjustable nozzle, fitted with a hand-lever, so that it can be quickly opened and shut."

"All these and other contrivances are more or less unsatisfactory. What is wanted, and what any engine intended to work regular traffic in crowded streets *must* have, is some contrivance by means of which it can at all times run in perfect silence, and yet constantly maintain as uniform a pressure as the ordinary puffing blast-pipe, so that it may go quietly up an incline, and yet have plenty of steam; or, again, run fast down a gradient without accumulating an excess of pressure. This great desideratum we most perfectly obtain as follows: On the axis of a silent fan discharging into a close ash-pan, fit a turbine or bucket wheel; then take the usual blast-nozzle out of the funnel, and cause the exhaust steam to be discharged against the turbine wheel, so as to rapidly rotate the fan. Then turn the exhaust into the water-tank, where part is condensed, and all water deposited, the remaining small amount of steam escaping gently through a wide pipe into the funnel, where, being small in quantity and free from water, it is superheated and passes off

noiselessly in an invisible form. From this arrangement it will be seen that the speed of the fan, and consequently the draught, will be as perfectly regulated as if the blast were in the funnel in the usual manner, for a moment's reflection will show that the two actions depend for their success on precisely the same principles, viz. that in any locomotive, the back pressure of the exhaust varies directly according to the power that the engine is giving out. With the ordinary funnel blast the draught through the boiler is created by *suction*, while with the exhaust-driver fan it is urged by *pressure*. With the latter, whenever the engine starts, the fan starts; if it stops, the fan stops; when going up an incline, the back pressure increases and the fan runs fast; when going down, it falls away, and the speed of the fan becomes in the most perfect measure reduced. It will thus be seen that as far as relates to their capability of regulating the intensity of a locomotive fire, the blast-pipe and the exhaust-driven fan stand on precisely the same footing. With the blast-pipe, however, the exhaust must of necessity be projected rapidly and violently into the atmosphere, while with the steam fan it can, after urging the draught, be still retained in the pipe, and so can be condensed, or otherwise noiselessly disposed of.

"This arrangement of exhaust-driven fan we call our 'blast-suppressor,' and *by it alone, and by no other contrivance, either yet made or proposed, is it possible to continuously work in silence a steam-driven locomotive without greatly impairing its efficiency.*"

"We have thus an engine thoroughly well adapted for working ordinary street railways of moderate gradients. *It has ample pulling and stopping powers; it runs in either direction; it can round any street curve; its working parts are unseen, yet quite accessible, and tolerably free from mud and*

dust; it is practically noiseless, smokeless, and steamless, and free from glare of fire by night; it can be worked with the greatest safety by merely a single attendant; the entire weight of both engine and car is steam braked; it is not complicated, and is of sightly appearance."

The above extracts are somewhat lengthy, but they are so pregnant with interesting matter and practical remarks that we think them worthy of being read by all who are interested in the economical working of tramways.

The use of steam power in the public streets is doubtless attended with many difficulties, but we venture to think they are not insurmountable. Mr. Todd has fairly grappled with the subject: he has, we think, made a considerable advance in the right direction, and we trust that he and other equally enterprising inventors will be encouraged by tramway companies and others to persevere in their useful work.

At present the English law prevents the use of steam on tramways, but it has for some time been in contemplation to pass an Act authorizing steam to be used. In 1873 a Select Committee of the House of Commons was appointed to inquire into the effect of the use of locomotive engines on the public roads, and although they were not instructed to express any opinion on the use of steam engines on tramways, they made the following statement in their report:

"The committee do not think it advisable to make any recommendation as to the employment of steam on tram-

ways, but they have received evidence that the power of control and stoppage is at least equal to that possessed over ordinary tramway cars, while there need not be any noise greater than that produced by the movement of the car."

This statement, spontaneously made, rather leads to the inference that the committee were not opposed to the introduction of steam on tramways, especially as after having entered fully into the question as to the effect produced on horses by steam engines, they reported:

"As small engines are now employed in all directions for contractors' work, steam fire-engines, &c., passing daily through streets and amongst horses, and as at most railway stations locomotives are habitually run within a few feet of horses and carriages, and as few or no accidents are known to result from these practices, it seems reasonable to conclude that horses in towns will not take much notice of the passage of road locomotives."

When tramway rails are wet or frosted it is very difficult indeed to get adhesion enough to drive an engine up inclines and round curves, and there are other obvious difficulties to be contended with besides those already hinted at. Among them should be mentioned the difficulty and loss of time likely to be experienced in replacing a mechanically worked engine on the tram rails, when it has accidentally run off the line. Where horses are used it is comparatively easy to keep the car on the rails, even where there are sharp curves, for they can be made to pull diagonally when required, and if by chance the car does leave the rails, the horses

can draw it on again. But where the propelling power is mechanical, if the wheel base is rigidly fixed, there is great risk of the engine or car being run off the line, for a sharp curve or slight obstruction on the rails will easily cause this to happen. This will be especially the case where grooved rails are used, as they so soon become choked with dirt and stones.

If "bogies" be used, this risk will be considerably reduced; and where grooved rails are not used, it may be assumed that with careful driving bogies will practically do away with it. Where grooved rails are used, the grooves and corresponding flanges on the wheels should be made as deep as possible.

Coiled springs have recently been suggested as motors for carriages; and Mr. E. H. Leveaux, of London, has contrived a clever arrangement by which he proposes to propel tramway cars. The springs must necessarily be very powerful, and are intended to be wound up by stationary steam engines placed at intervals along the tramway routes. We think Mr. Leveaux's invention superior to the "fireless" engine, because, however long a car may be kept standing, there will not be any loss of power in the springs, whereas in the "fireless" engine every minute adds to the loss of heat and consequent diminution of power. But there are other points to consider. At present, in busy thoroughfares, thronged with vehicles of all kinds, it is difficult for the tramway cars to maintain an average speed of five miles an hour, or even less; and in practice some of the London omnibuses are able to reach their destinations

more quickly than the tramway cars, because they are not obliged to travel in a fixed line, but can steer diagonally between other vehicles. If, therefore, the cars have to be stopped at intermediate stations, in order that the springs may be wound up, a new element of delay will be introduced. Special provision will also be required to reduce the liability of the cars to run off the rails, and to make the replacing of them easy and expeditious; also to ensure their being run round the sharp curves and up the steep inclines, so often necessary.

IV. WORKING OF TRAFFIC, CHECKING RECEIPTS, ETC.

We have now to notice several points which have a practical bearing on the successful working of tramways, and which should be taken into account in laying down a line and in organizing the traffic arrangements.

The smooth rails of a tramway of course offer much less resistance to the running of a carriage than the uneven surface of an ordinary road, whether paved or macadamized. When on a level or nearly so, it is found in practice that a pair of horses can draw about double the load on a tramway that they can on an ordinary road; but on inclines, although the smooth rails make the traction easier, the force of gravity tending to draw the car backwards is not counteracted in any appreciable degree by friction, and if heavy cars are used, the strain on the horses is seriously increased on inclines steeper than 1 in 50 or 45. On this account, as well as for economy in working, steep gradients should be avoided, or if used, they should be as short as possible. The cars should not be stopped when going up a steep incline, and when running down, efficient brakes must be used to prevent too high a velocity being attained.

Double Lines.—It is important for tramway cars to be subject to few detentions, so that not only may passengers be quickly conveyed to their destinations, but

the convenience of persons in other vehicles using the public road may not be interfered with. It is therefore desirable in all busy localities to have a double line; and where this is not practicable in one street, a second line should be laid along another street as nearly parallel to the first as may be, the two being connected by cross lines. In some places, as in Philadelphia and Liverpool, a circular line is used, and the cars are always run round in one direction. In outlying districts, where there is not a large traffic, a single line, with passing places at suitable intervals, will answer the purpose; but such an arrangement will not be satisfactory in much-frequented streets.

Captain Tyler, in a Report to the Board of Trade, remarks:

"It is important, in the working of the traffic, to provide as far as possible that the cars shall not in any case come to a dead end, at which one car may have to stand and await the arrival of another before commencing its return journey; or at which the horses, being detached on arrival from one end, shall be taken round the car and reattached at the other end of it, before commencing a fresh journey in the opposite direction. In fact, one of the most important points to be considered in the working arrangements of the cars, as far as the avoidance of obstructions in the streets is concerned, is to keep each car moving in the same direction from the time it commences work in the morning until it returns to its yard in the evening; no more rest being allowed to it than is necessary for changing horses at the appointed places; and the more crowded the streets through which it passes, the more necessary does this condition of working become. It is obvious that the less time there is consumed

in stoppages, the fewer, as a general rule, will be the number of cars required to do a given amount of work in the conveyance of passengers. And there can hardly be much objection to single-line routes, without passing or crossing places, through streets that are suitable for them, provided they are not so long as to require more than one car to be on them at one time."

"As regards danger to foot-passengers, there can in no case be the same risk with tramway cars as with omnibuses. The foot-passenger has only to look for a car along its own track, while he must be on the look-out for omnibuses along every part of the streets which they traverse."

We quite concur in the above remarks, especially as to the desirability of not letting cars "come to a dead end" in any narrow or busy street. The changing of horses, &c., should take place in less inconvenient places; and where steam cars are used provision must be made for their being reversed at the end of each journey, or they must be run round a circular loop line.

We think we may safely affirm that experience in all parts of the world shows that tramways, except in very narrow streets, do not obstruct but rather tend to regulate and give a direction to the ordinary street traffic.

The evidence of several police superintendents as to whether or not tramways were injurious to the public was taken before the Select Committee of both Houses of Parliament, appointed in 1872, relative to the proposed extension of the metropolitan tramways. The superintendents stated that objections could not well be urged against the tramways except where the horse-track was paved and the road on each side of it mac-

adamized, for then the edge of the paving was nearly always above the surface of the macadam, owing to the latter being sooner worn away. But they all seemed to agree that were this defect remedied, and were the permanent way and paving kept in thorough repair, tramways could not be said to be objectionable, while they are certainly a great convenience to large numbers of the public.

Before the same committee Captain Tyler stated:

"I have noticed that as the cars go along they rather make way for the faster traffic through crowded streets than obstruct it, and by carrying a greater number of people in each car than an omnibus, I think they are rather an advantage than otherwise."

To ensure the convenience of the public being interfered with as little as possible in working a tramway, the English Tramways Act, 1870, gives to the local authority of any district in which a tramway is laid down power to make regulations as to the following matters:

"The rate of speed to be observed in travelling upon the tramway; the distance at which carriages using the tramway shall be allowed to follow one after the other; the stopping of carriages using the tramway; the traffic on the road in which the tramway is laid."

This Act also provides that:

"Every tramway in a town which is hereafter authorized by Provisional Order, shall be constructed and maintained as nearly as may be in the middle of the road; and no tramway shall be authorized by any Provisional Order to be so laid

that for a distance of 30 feet or upwards a less space than 9′ 6″ shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway, if one third of the owners or one third of the occupiers of the houses, shops, or warehouses, abutting upon the part of the road where such less space shall intervene as aforesaid, shall in the prescribed manner and at the prescribed time express their dissent from any tramway being so laid."

The object of this provision is to enable carts and other vehicles to be driven between the tram rail and the kerb, or to be stopped in front of a house or shop, without being interfered with by the tramway cars. This is a very desirable stipulation, but in many places, especially in the outskirts of a town, it is unnecessary to reserve so great a width.

The extreme outside width allowed by the above Act for tramway cars is "11 inches beyond the outer edge of the wheels," so that the distance between the car and the kerb is practically reduced to about 8 feet 8 inches, whilst the extreme width from outside to outside of the wheels of a four-wheeled cab is 5′ 2″, of a hansom cab 6′ 2″, of an ordinary omnibus 6′ 8″, and of ordinary carts about 6′ 6″. In the City of London it is found sufficient to make streets intended for two lines of vehicles 14 feet wide, but a width of 15 feet is preferred. And speaking generally, it may be said that the minimum widths of streets on which tramways can be satisfactorily worked, where there is a large general traffic, are: for a double line, from 32 to 33 feet; and for a single line, from 23 to 24 feet.

Sometimes the cars of one company are by agreement allowed to run over the line of another company. This is so in Philadelphia, and there the company who constructed the line are paid by the other companies using it 10 per cent. per annum on the cost of construction and a share of the cost of up-keep.

In towns, the profits of a tramway largely depend on the frequency and regularity with which the cars are run. Passengers have often only short distances to go, and if they know they must wait several minutes for a car, they will generally walk; but if they know for certain that they can take a car almost immediately they will generally be tempted to ride. If the fare is uniform for any distance (as on many lines), two passengers who ride short distances will yield about double the profit of one passenger who rides the whole length of the tramway. Where the fare is not uniform, two passengers who ride short distances will yield about one and a half times the profit derived from one passenger who travels over the whole line.

In the United States a frequent service of cars has been fully recognized as an element of success, and in nearly all busy towns the cars are run at intervals of from two to five minutes. In New York City and Brooklyn the cars are run all day and night. From about 7 to 10 A.M., and from 3 to 8 P.M., they follow at intervals of about two or three minutes; from 8 P.M. to midnight they follow at intervals of from five to eight or ten minutes; and on the chief lines after midnight they are run at intervals of from fifteen to thirty

minutes, according to the requirements of the traffic. By this means nearly every person is induced to ride instead of to walk, and the tramway car has almost everywhere in the United States superseded the less convenient omnibus: in fact, the latter has in many places been fairly driven off the road by competition.

In places where the distance to be travelled is too great for walking, passengers can be more easily secured; and if the traffic is not very great, the cars can be run at long intervals without danger of losing passengers. As a general rule, the financial success of a tramway much depends on the running of the cars being so arranged that the intervals between them shall not be long enough to make it worth while for passengers to walk instead of to ride.

To carry out such a rapid service effectually, it is not only necessary to provide up and down lines, but to keep them as nearly as possible free from the ordinary street traffic. This in some places, especially in many of the busy streets of London, would not be possible. In New York and other American cities, all classes of the people have, however, become so used to ride in the tramway cars, and long habit has made them feel so great a need of them, that the regular working of the cars is looked upon as more important than the interference with a portion of the ordinary street traffic.

To give an idea of the amount of tramway traffic actually carried on in some parts of New York City, we may mention that along Church Street, which is only 20 feet wide, there are four lines of way, and on each of these

lines cars are running from 7 A.M. to 7 P.M. at intervals of about two minutes. This gives a total of about 120 cars per hour, or 1440 in twelve hours. In Ann Street, which is under 17 feet wide, there are twenty-two cars per hour between 10 A.M. and 6 P.M. The average number of passengers now carried in each year on the tramways in Philadelphia is about 65,000,000, and in Brooklyn and New York City no less than about 200,000,000. No better proof than this can be given of the surprising extent to which tramways are there used.

Fares.—At the last meeting of the Social Science Association, the President, Lord Rosebery, pointed out that municipal improvements and the increased value of land in towns make it necessary for the working classes to seek dwellings outside the towns; but that as this has carried them away from their occupations, it becomes necessary for them to have a cheap and easy means of locomotion. Lord Rosebery considered that in a great measure this can be effected by tramways, and he remarked "they are the inconvenience of the opulent and the luxury of the poor." This is doubtless very true to a great extent, although their use, even in this country, is by no means restricted to the artisan classes, for thousands of business men and women of all kinds gladly use them. They are, however, essentially for those who cannot afford to pay much for the convenience of riding, and *cheap* fares should therefore be adopted.

In this country one penny per mile is the *maximum*

authorized fare, but on most lines less than this is charged. Americans are accustomed to pay much more than Englishmen for almost everything, yet the usual tramway fares in the United States do not exceed five to seven cents for a journey from end to end of any line. In New York City a uniform fare of five cents (about 2½*d.*) is charged on all the lines, and no tickets are used. But in many other American cities tickets are used, and when several are bought a rebate is allowed. Thus where a single fare is, say, six cents, twenty tickets are sold for a dollar, or at the rate of five cents each. In Philadelphia counters are used, made of horn or hard indiarubber composition. These are sold at various places, and in all the cars. Each counter entitles the holder to a single journey on any company's line, and if a passenger requires to travel on the lines of two different companies (supposing his destination cannot be reached by one direct line), he can, on presenting a counter at the end of his ride on the first line, obtain an "exchange" from the conductor for half a fare more to complete his journey.

Checking Receipts of Conductors.—Various means have been tried to ensure all the money paid by passengers being handed over to the tramway proprietors; but all the check systems hitherto tried are either inefficient, or interfere too much with the convenience and comfort of passengers; and the most difficult task of a tramway manager is to prevent any tampering with the traffic receipts.

On an ordinary railway, no passenger is allowed to

travel without having purchased a ticket before entering the train, and he knows that not only at his destination but at intermediate stations he may at any time be called on to produce it, and so he cannot possibly travel without paying his fare. Besides this, all tickets are issued from a booking office; the clerk there is obliged to account to his employers for every ticket issued, and no money can be dishonestly taken by him. Nor can there be collusion between the passenger and the different sets of officials who may call on him to produce his ticket. Thus the check is practically perfect.

On a street railway or tramway it is, however, very different; for although on some lines tickets are sold to those passengers who take the trouble to purchase them beforehand, the majority of those who ride in tramway cars are not ticket-holders, but pay their fares in money to the conductor. At the end of each journey the conductor is supposed to hand over all he has received; but as there is no intermediate collector, he is tempted to keep back some portion of the earnings. On many lines tickets with counterfoils are given to the conductors; but this is practically no check, for the conductor who issues the tickets also collects them, and he can find the means of reissuing old tickets for his own particular benefit.

Where the fares are uniform it is more easy to check the receipts by mechanical means; but where two or more different fares are charged, as on nearly all the English lines, it is found practically impossible to ascertain the exact amount received by the conductors.

Dials with bells attached are extensively used on the Continent; but in England the public are either too negligent or too indifferent to see that the conductor correctly records the number of passengers, and they are practically useless. We recently advised the directors of a tramway company to offer a premium for the best system of checking the receipts of conductors, and as a consequence we had to investigate the proposals of no less than forty-five competitors; but although many showed great ingenuity, not one of them met the real difficulty of *compelling* the conductors to give correct returns of their receipts.

In the United States, a glass fare-box* is extensively used; and since its first adoption at New Orleans, in 1861, it has been found to answer on lines where small cars are used, and where the number of passengers is not very great. Where it has been used, the traffic returns have augmented, and in some cases they have even doubled. But this system cannot be depended on where the fares are varying, or where there are very many passengers to attend to.

A more recent invention is the "bell-punch" system. In this every passenger is required to take a ticket from the conductor, who carries a small punch with which he is required to punch a hole in every ticket he issues. The punch is so contrived that every time it is used a little bell rings inside the framework, and the conductor cannot pretend to punch an old ticket

* See page 22.

without ringing the bell. When this bell rings a record is automatically made on a dial, thus registering the number of passengers to whom tickets are issued. This is an ingenious invention, and is found to answer better than the other check systems hitherto tried; but the royalty asked for its use in this country is so great, that it has prevented its being generally adopted.

Registering turnstiles have been tried, but they are found practically unworkable in the United States and this country, for the space at the ends of the cars where passengers have not only to enter but to leave, is too confined, and as tramway companies have to cater for the public, they cannot adopt a contrivance of which the public disapprove.

It is estimated that the London General Omnibus Company and several tramway companies lose about 10 per cent. of the gross receipts of the conductors, and on some lines the loss is believed to be even more: the great importance of this subject cannot therefore be overlooked. A tramway conductor, in New York, on being asked as to how he managed to live on his pay, naïvely remarked that his pay was not a "circumstance," and that he did not pretend to live on his salary, but on his perquisites. A careful selection of drivers and conductors will, to a certain extent, prevent dishonest dealings, but this cannot be relied on, and the following may be given as a practical illustration of the intimidation and corruption practised. On a well-known London line the manager removed some conductors suspected

of dishonesty, and replaced them by men of undoubtedly good character, whose honesty was vouched for by responsible persons. This is what followed: On the first day the money handed in by the new conductors was considerably in excess of what had been received from the dismissed conductors. On the second and third day there was a similar result. The manager praised the conductors, and was hopeful that at last he had put an end to the pilferings. On the fourth day, however, there was a marked change for the worse; and on the fifth and sixth days the result was even more unsatisfactory. On being pressed for an explanation, one of the new conductors said that it was simply this. On the first day his driver was very civil, and did all he could to procure passengers, so that the earnings might be as much as possible. On the second day, the driver intimated that it was usual for the conductor to treat him with a chop and some brandy. The new conductor declared he would not rob his employers for the sake of the driver, and the latter simply said he would compel him to do so. The driver, however, continued to assist the conductor to get as many passengers as possible. On the third day, he repeated his request to be treated, but the conductor still refused. On the fourth day, the driver took the offensive, and intimated to the conductor that unless he treated him in the usual way he would not stop the car for passengers, so that the conductor's earnings should be considerably reduced. He said the directors knew from the returns of the three previous days what the conductor could earn,

and that if they found there was a sudden diminution they would suspect the conductor of dishonesty and probably dismiss him; and to ensure this result he added that he would tell the manager that the earnings had been the same as before, and that the difference in amount had been taken by the conductor for his own use. The conductor held out, and the driver fulfilled his threat, the effect of which was an immediate decrease in the receipts.

It is of course impossible to ensure that all the drivers and all the conductors shall not only be strictly honest when they are first engaged, but that they shall remain so when temptation has been put in their way, and when they have learnt how easy it is to evade detection. Every encouragement should therefore be given to inventors for mechanical or other suitable means of *compelling* conductors to account for all they receive; and until a satisfactory system is adopted the profits of tramway and omnibus companies will continue to be seriously affected.

V. CONCLUDING REMARKS.

Tramways are undoubtedly popular in America, and in many instances they yield remunerative profits. In the United States and Canada there is hardly a city with a population of 10,000 to 15,000 in which there is not at least one line. In the State and City of New York there are over eighty different companies whose lines are situated either wholly or partly in that State. In fact, in the United States, as we have already mentioned, tramways are used by all classes of society, and are considered necessary public institutions. They have been extended in the most comprehensive manner along the busy lines of traffic in nearly all the large cities, so that passengers can ride to and from nearly all the leading places, and consequently very few people think it worth while to walk.

In England, no comprehensive system has yet been tried; all the lines at present in use are independent and do not correspond with one another. This is especially the case in London, where tramways are entirely prohibited in the City, and where they cannot even be laid across the bridges over the Thames, nor along many of the chief omnibus routes, such as Oxford Street, Tottenham Court Road, &c. The reason of this is partly because there are so many different road authorities whose sanction it is necessary to obtain, but from whom it is practically impossible to look for

united action; for they consist of such heterogeneous bodies as the Corporation of London, the Metropolitan Board of Works, and the different Vestries. The chief reason, however, of tramways not having been more generally tried in this country, is that they are not considered so necessary here as in countries not so well supplied with other public vehicles.

Captain Tyler well explains this in the following remarks:

"The comparatively good condition of the road surfaces, the common use of cabs and omnibuses, and the number of those vehicles available for general purposes at reasonable fares, have all combined to render tram rails less necessary here than elsewhere. The numbers of private vehicles in use, whose owners naturally look upon tramways with suspicion, if not with absolute dislike, are also greater. Certain vested interests are or have been more or less opposed to tramways; the numerous bodies by whom the streets are owned or maintained are difficult to deal with, with a view to combined permissions for complete tramway routes; and the existing railway and omnibus companies cannot, in many cases, consider tramway companies otherwise than as formidable competitors."

And he adds:

"In the principal cities of the United States of America the street-car is, as I have observed in that country, an indispensable institution. The long distances to be traversed, the generally bad condition of the streets and roads, and the comparative want of other vehicles, combine to bring it into constant use for all classes; and the habits of the people having thus been formed, the irregularities between the rails and the roads are of less importance than in this country,

where the great majority of vehicles for street traffic require a good road only, and are inconvenienced rather than benefited by a tramway.

"Under these circumstances, while it is plain, on the one hand, that street tramways, with cars affording superior accommodation, conveying greater numbers of passengers, running at higher speed, and charging lower fares than the ordinary omnibuses, would be of immense advantage to travellers to and from the suburbs of London, in the larger towns and cities of this country, and along certain of the country roads, it is very desirable, on the other hand, that the tramways should be so laid, and so kept in repair, as not to become a source of annoyance, and an occasion of complaint, to the owners or drivers of vehicles using the roads and not wishing to use the tramways."

We are glad to state that, even with the drawback of not being able to approach the great centres of traffic, and to run along the leading thoroughfares, and notwithstanding the numerous restrictions imposed upon them, the tramway companies now at work in London are earning remunerative returns; and when longer experience has taught them how to reduce further the working expenses, and to check more completely the receipts of the conductors, they will rank as financially successful undertakings.

The large development of the railway system in all parts of England during the last fifteen or twenty years, has led persons of all classes to travel much more than formerly, and it is almost a truism to say that increased facilities for locomotion almost invariably lead to increased traffic. Of necessity, the greater the number of passengers conveyed from the provinces to a town,

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The large development of the railway system in all parts of England during the last fifteen or twenty years, has led persons of all classes to travel much more than formerly, and it is almost a truism to say that increased facilities for locomotion almost invariably lead to increased traffic. Of necessity, the greater the number of passengers conveyed from the provinces to a town,

the more are the streets of that town crowded; and an increasing want is then felt of a cheap and easy means of conveyance to and from places of business and of general resort. Omnibuses supply this want to a great extent, but in many places tramways are better fitted for the work: and this has been proved in New York, Brooklyn, Philadelphia, and other American cities, where the use of tramways has almost entirely superseded that of omnibuses; in fact, the owners of the latter have been obliged to yield to the competition of the superior vehicles, and to remove the omnibuses from the tramway routes.

On the other hand, in England, where the tramway system is not a comprehensive one, the omnibus traffic has not suffered as was expected; on the contrary, the traffic returns of the London General Omnibus Company show that the receipts have increased since the introduction of tramways in London.

We are inclined to think there is a large and profitable opening for tramways in many parts of England, but at the same time we entirely agree with the following observations of Captain Tyler:

"From what I have seen of street tramways in this country and in America, I am quite disposed to believe that they will be beneficial in an important degree in affording increased facilities for communication to the great mass of the population in the districts in which they are laid down, though they must be, to some extent, an inconvenience—and much more in this country than in America—to those who require or

desire to use the streets with vehicles other than tramway cars. The measure of this inconvenience will depend, partly upon the care and efficiency with which the tramway traffic is worked, and partly upon the way in which the street surfaces are constructed, and the condition in which they are maintained. Without underrating the importance of the former, it may be stated that the success or failure of the tramway system will depend mainly upon the latter of these two conditions."

No general rule can be given for estimating the probable revenue of a proposed line of tramway, as this must, of course, depend to a great extent on local circumstances. In all cases great care should be taken in the selection of the routes, and the cost of construction and equipment should be fairly proportioned to the probable amount of traffic. Several of the lines first tried in America were badly designed and constructed, and had to be relaid at great extra expense; besides this, over sanguine promoters under-estimated the first cost, and over-estimated the probable profits, and loans had to be raised to complete the construction, as well as provide for the equipment. For these reasons many of the early companies were unsuccessful, but those more recently formed profited by the experience gained on the lines first made, and adopted more efficient and at the same time less costly modes of construction. On the whole, tramways are now looked on in America as sound permanent investments, and they certainly pay extremely well in many European cities.

A noticeable feature in tramways is, that when once

they have been fairly established their earnings are nearly constant; they do not depend on the carriage of merchandise, and are very little influenced by the fluctuations of trade. Even in times of commercial panic there is little or no diminution in the number of passengers.

[APPENDIX (A).

URT

DWAY (			Central Park, North and East River.			
72.		1874.	1871.	1872.	1873.	1874.
$ 7,600	84	* $	$ 1,629,175	$ 1,871,175	$ 1,948,586	* $
3,749	58		274,956	302,667	313,155	
9,006	62		577,092	599,818	566,808	
3,711	98		590,246	639,304	585,805	
·8			97·7	93·1	96·8	
·5			0·8	2·0	0·9	

EET AN			Third Avenue.			
72.		1874.	1871.	1872.	1873.	1874.
$ 1,679	60	* $	$ 3,061,241	$ 3,450,939	$ 3,757,365	* $
7,437	36		397,193	462,086	476,921	
3,511	84		..	1,259,119	1,323,091	
7,675	85		..	1,625,592	2,049,312	
·7			..	77·4	64·5	
·4			..	10·6	19·2	

port fo

[*To face page* 62.

APPENDIX (B).

Extract from General Railroad Act relating to Horse Railroads in the State of New York.

§ 2. "Every railroad corporation in this State whose road is operated by horse power exclusively, or by steam-dummy cars exclusively, or partly by horse power and partly by steam-dummy cars, and every such railroad corporation which shall hereafter be organized, shall make an annual report to the State Engineer and Surveyor of the operations of the year ending on the 30th day of September; which report shall be verified by the oaths of the treasurer or president and acting superintendent of operations, and be filed in the office of the State Engineer and Surveyor by the 1st of December in each year, and shall state:

1. The amount of capital stock.
2. The amount of stock subscribed.
3. The amount paid in, as by last report.
4. The total amount now of capital stock paid in.
5. The funded debt, as by last report.
6. The total amount now of funded debt.
7. The floating debt, as by last report.
8. The amount now of floating debt.
9. The total amount now of funded and floating debt.
10. The average rate per annum of interest on funded debt.

Cost of Road and Equipment.

11. For road-bed and superstructure, including iron, by last report.
12. The total amount now expended for the same.
13. For land, buildings, and fixtures, including land damages, by last report.
14. The total amount now expended for the same.
15. For dummy cars, horses, mules, and harness, by last report.
16. The total amount now expended for the same.
17. For cars and sleighs, by last report.
18. The total amount now expended for the same.
19. Total cost of road and equipment.

Characteristics of Road.

20. Length of road, in miles.
21. Length of road laid.
22. Length of double track, including sidings.
23. Weight of rail, by yard.
24. The number of dummy cars, of cars, and of horses and mules.
25. The total number of passengers carried in cars.
26. The total number of tons of freight carried in cars.
27. The rate of fare for passengers.
28. The average time consumed by passenger cars in passing over the road.

Expenses of Maintaining the Road and Real Estate.

29. Repairs of road-bed and railway (including iron), and repairs of buildings and fixtures.
30. Taxes on real estate (to include all taxes, except for United States revenue).
31. Total cost of maintaining road of real estate.

Expenses of Operating Road, and for Repairs.

32. General superintendence.
33. Officers, clerks, agents, and office expenses.
34. Conductors, drivers, and engineers on dummy cars.
35. Watchmen, starters, switchmen, roadmen, &c.
36. Repairs of dummy cars.
37. Repairs of cars and sleighs.
38. Repairs of harness, including materials and labour.
39. Horse-shoeing, including materials and labour.
40. Horses and mules.
41. Stable expenses.
42. Feed, grain, hay, &c., including expense of grinding.
43. Fuel, gas, and lights.
44. Oil and waste.
45. Water tax.
46. Damages to persons and property, including medical attendance.
47. Law expenses.
48. Rents, including use of other roads, ferries, &c.
49. Insurance.
50. Advertising and printing.
51. United States tax on earnings.
52. Contingencies.

53. Total expense of operating road and repairs.
54. Receipts from passengers.
55. Receipts from freight.
56. Receipts from all other sources, specifying what, in detail.
57. Total receipts from all sources during the year.
58. Payments for transportation, maintenance, and repairs.
59. Payments for interest.
60. Payments for dividends on stock, amount, and rate per cent.
61. All other payments, specifying what, in detail.
62. Total payments during the year.
63. The number of persons injured in life and limb; the cause of the injury, and whether passengers, employés, or other persons. Also whether such accidents have arisen from carelessness or negligence of any person in the employment of such corporation, and whether such person is retained in the service of the corporation.

§ 3. "Any railroad corporation which shall neglect to make the report, as is provided in the preceding section, shall be liable to a penalty of 250 dollars, and an additional penalty of 25 dollars for each day after the 1st day of December, on which they shall neglect to file said report, as provided in said section, to be sued for in the name of the people of the State of New York, for their use."

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Plate 7. Marine Engine, Direct Action for the Screw Propeller, 400 H.P. Collectively; Scale ¾ in. = 1 foot; 7 Views.

Plate 8. Details of One Marine Engine, 200 H.P.; Condenser and Air Pump, Feed and Bilge Pumps, Cylinder, Equilibrium Slide Valve and Casing, Main Frame, Connecting Rod; Scale 2 in. = 1 foot; Guide Block and Cross Head—Scale 2 in. = 1 foot; Discharge and Suction Valves for Air Pump, 3 in. = 1 foot.

Plate 9. Details of One Marine Engine, 200 H.P.

Eccentrics and Straps, Solid Valve Link and Block, Slide Valve Rod and Guide, Blow-through Valve, Shifting Valve, Relief Valve, Bilge and Feed Pump Valves, Spur Wheel for Expansion Gear, Kingston and Injection Valves; Scale 3 in. = 1 foot. Crank Shaft; Scale 1½ in. = 1 foot.

Marine Engines (*continued*).

Plate 10. Details of One Marine Engine, 200 H.P.; Scale 3 in. = 1 foot.
Air Valves for Air Pumps, Steam Piston Injection Pipe, Air Pump Plunger, Air, Feed, and Bilge Pump Rods, Blow-through Valve for Condenser, Bracket for Reversing Gear, Drain Cock and Handle for Condenser.

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Plate 12. Oscillating Engines for the Paddle Wheel, 150 H.P., Collectively; Scale 1 in. = 1 foot; 7 Views.

Plate 13. Paddle Feathering Wheel, 75 H.P.; Scale 1 in. = 1 foot; 2 Views.

Plate 14. Details of Paddle Wheel, 75 H.P.
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Plate 15. Griffith Patent Screw Propeller, with Lifting Frame; Scale 1½ in. = 1 foot.

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Plate 17. Marine Boiler, with Superheating Tubes; Scale 1 in. = 1 foot; 6 Views.

Plate 18. Ordinary Condenser, and Air Pump, for Screw Marine Engine, 200 H.P., and Oscillating Paddle Engine, 75 H.P.; 8 Views.

Plate 19. Surface Condenser, 200 H.P.; Scale 1½ in. = 1 foot; 4 Views.

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